The Use of a High Fidelity Simulator to Improve Aircraft Inspection Performance: The ASSIST Program

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ABSTRACT

The aircraft maintenance industry is a complex system consisting of several interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the Federal Aviation Administration (FAA) has pursued human factors related research. In the maintenance arena the research has focused on the aircraft inspection process and the aircraft inspector. Training has been identified as the primary intervention strategy to improve the quality and reliability of aircraft inspection. In response to this need, the paper outlines the development of a high fidelity inspection training simulator (ASSIST: Automated System of Self Instruction for Specialized Training) focused on improving aircraft inspection performance and ultimately aviation safety. The research was funded by the Federal Aviation Administration and conducted by the Advanced Training Systems Laboratory of the Department of Industrial Engineering, Clemson University and was conducted in cooperation with Delta Airlines and Lockheed Martin Aircraft Center.

INTRODUCTION

Aircraft inspection and maintenance are an essential part of a safe, reliable air transportation system. Training has been identified as the primary intervention strategy in improving inspection performance. If training is to be successful, we need to provide inspectors with training tools to help enhance their inspection skills. In response to this need, this paper outlines recent efforts being pursued by the Advanced Training System Laboratory at Clemson University focused on the development of a computer based inspection training program - Automated System of Self Instruction for Specialized Training (ASSIST). The ASSIST program was developed using a task analytic methodology.

Existing training for inspectors in the aircraft maintenance environment tends to be mostly on-the-job (OJT). However, this method may not be the best one because feedback may be infrequent, unmethodical, and/or delayed. Moreover, in certain instances feedback is economically prohibitive or impractical because of the nature of the task. Because the benefits of feedback in training have been well documented (e.g. Weiner, 1975), and for other reasons as well, alternatives to OJT are sought.

More importantly, training for improving the visual inspection skills of aircraft inspectors is generally lacking at aircraft repair centers and maintenance facilities even though the application of training knowledge to enhance visual inspection skills has been well documented in the manufacturing industry. Training has been shown to improve the performance of both novice and experienced inspectors (Weiner, 1975; Drury, et al., 1990; Gramopadhye, et al., 1995). Visual inspection skills can be taught effectively using representative photographic images showing a wide range of conditions with immediate feedback on the trainee's decision (Weiner, 1975). Using realistic photographic images as a training aid in controlled practice with feedback has also been shown to be superior to only On-the Job Training (OJT) (Gramopadhye, et al., 1995; Latorella, et al., 1992)

Thus, off-line training/retraining with feedback has a role to play in aircraft inspection training. One of the most viable approaches for delivering training given the many constraints and requirements imposed by the aircraft maintenance environment is computer-based training. Computer-based training offers several advantages relative to traditional training approaches; for example, computer-based training is more efficient, facilitates standardization, and supports distance learning. With computer technology becoming cheaper, the future will bring an increased application of advanced technology in training. Over the past decade, instructional technologists have offered numerous technology based training devices with the promise of improved efficiency and effectiveness. These training devices are being applied to a variety of technical training applications. Examples of such technology include computer-based simulation, interactive videodiscs and other derivatives of computer based applications. Compact disc read only memory (CD-ROM) and Digital Video Interactive (DVI) are two other technologies which will provide us with the "multi-media" training systems of the future. Many of these training delivery systems such as computer aided instruction, computer based multi-media training and intelligent tutoring systems are already being used today, thus ushering in a revolution in training.

In the domain of visual inspection, the earliest efforts to use computers for off-line inspection training were reported by Czaja and Drury (Czaja, et al., 1981). They used keyboard characters to develop a computer simulation of a visual inspection task. Similar simulations have also been used by other researchers to study inspection performance in a laboratory setting (e.g., Mckernan, 1989). Since these early efforts, Latorella et al., (Latorella, et al., 1992) and Gramopadhye, Drury and Sharit (Gramopadhye, et al., 1994) have used low fidelity inspection simulators using computer generated images to develop off-line inspection training programs for inspection tasks. Similarly, Drury and Chia-Fen (Drury, et al., 1995) studied human performance using a high fidelity computer simulation of a printed circuit board inspection. Another domain which has seen the application of advanced technology is that of inspection of x-rays for medical practice (e.g., Kundel, et al., 1990). In summary, most of the work in the application of advanced technology to inspection training has focused on developing low fidelity simulators for running controlled studies in a laboratory environment (e.g., computer simulated line judgment task – Micalizzi, et al., 1989). Thus, research efforts need to be extended in order to take full advantage of today's computer technology. Moreover, advanced technology has found limited application for inspection training in the aircraft maintenance environment. Presently, most of the applications of computer technology to training have been restricted to the defense/aviation industry for complex diagnostic tasks. The message is clear: we need more examples of the application of advanced technology to training for inspection tasks that draw upon the principles of training which we already know will work. In this vein, this paper describes a university/industry collaborative research effort to develop an off-line computer based inspection training system for aircraft inspectors. The specific objective of this research was to develop an inspection training system which would improve the visual search and decision making skills of aircraft inspectors. The computer based inspection training program entitled "Automated System of Self Instruction for Specialized Training" (ASSIST) was developed in cooperation with Lockheed Martin Aircraft Center and Delta Air Lines. A brief description of the of the system follows.

ASSIST: AN AIRCRAFT INSPECTOR TRAINING SOFTWARE

System Specifications

The computer-based training program was developed using Visual C++, Visual Basic and Microsoft Access. The development work was conducted on a Pentium 120 MHz platform with a 17" high resolution monitor, 32 MB RAM, 2 MB video RAM, ATI Mach 32 VLB advanced graphics accelerator card, 810 MB hard drive, multi-speed CD drive, 210 MB Bernoulli drive and a Reveal multimedia kit. The training program uses text, graphics, animation and audio. The input devises are a keyboard and a two-button mouse.

System Structure

ASSIST software (see Figure 1) consists of three major modules: (1) the General Inspection Module, (2) the Inspection Simulation Training Module, and (3) the Instructor's Utilities Module. All system users interact through a user-friendly interface which capitalizes on graphical user interface technologies and human factors research on information presentation (e.g., color, formatting, layout, etc.), ease of use, and information utilization.

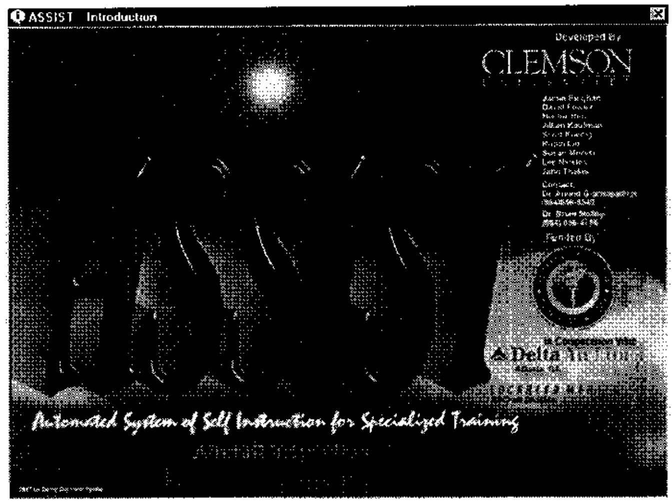

Figure 1: Introduction Screen from the ASSIST Software

General Module

The objective of the general module, which presents information through text, pictures, audio, and video, is to provide the inspectors with an overview of the following sub-modules (Figure 2): (1) role of the inspector, (2) safety, (3) aircraft review, (4) factors affecting inspection, and (5) inspection procedure. The module incorporates multimedia (sound, graphic, text, pictures and video) with interaction opportunities between the user and the computer.

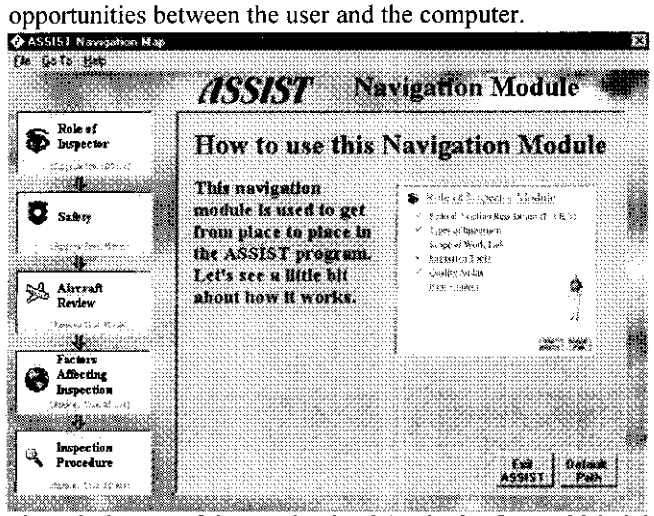

Figure2: Screen of the Navigation Map in the General Module

Inspection Simulation Training Module

This module of the training program provides inspection training on a simulated aircraft inspection task: the aft cargo bin inspection of a Lockheed Martin L-1011-Figure 3). By manipulating the various task complexity factors the instructor can simulate different inspection scenarios. The training module is further divided into four major sub-modules: introduction, search training, decision training and testing. Each sub-module uses computer-generated images of the airframe structure. The simulation module uses actual photographs of the airframe structure with computer-generated defects.

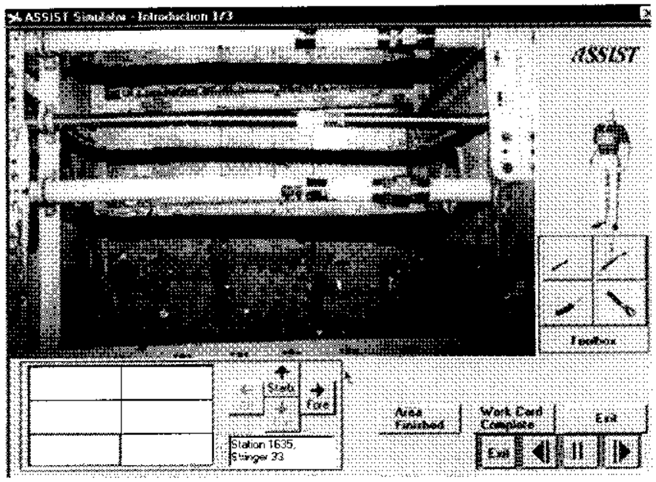

Figure 3: The Simulator from the Inspection Module

Introduction. The introduction provides the trainee with an overview of the various facets of the program, information on aircraft terminology and a representation of various faults. The section introduces the trainee to the search and decision making aspects of the visual inspection task. Each section is followed by a question and answer session wherein the trainee has to make an active response as each piece of new material is presented. The trainee is provided with immediate feedback as to its correctness. If an error is made, it is identified and the correct answer is supplied.

Search Training. The module trains the inspector on the search component of the visual inspection task. The objective is to train inspectors to correctly identify and locate defects. This type of training is aimed at developing cues, knowledge of where specific defects occur, and the use of feed-forward information. The trainee is provided with immediate feedback on the following speed and accuracy measures: the time to locate the defect (search time), and the accuracy of the search process (the program lets the inspector know whether he/she correctly identified the defect and marks the defect on the computer screen).

Decision Training. This module trains the inspector on the decision making component. A series of aircraft structures are displayed with the faults marked. After each image is displayed, the inspector makes an active response. First, the trainee classifies the defect by defect name. Following defect classification, the trainee writes up a Non-Routine Report-NRR report (if required) based on the number of defects, defect type, severity and location. The inspector is provided with immediate feedback on his or her decision making performance. The general objective of this module is to train the inspector on both the rule-based and knowledge-based aspects of the decision component of the inspection task.

Testing. The testing module is designed to operate in two separate modes: with and without feedback. The non-feedback mode simulates the actual visual inspection task (as it would take place on a hangar floor). In either mode, the inspector first locates the defect and indicates this by clicking on the fault. Subsequently, the inspector classifies the defect. In the feedback mode, the inspector is provided with immediate feedback on his/her performance on the search and decision making components of the inspection task. The trainee is also provided with end-of-session performance feedback.

Instructor's Utilities Module and Start-up Module

The Instructor Utilities Module allows the supervisor/instructor to access the results database, the image database and the inspection parameter modules. The start-up module allows the instructor to select images from the image database and store them in a batch file for use with the inspection simulator.

INSPECTION TRAINING SESSION

The training program was designed to use the general principles listed earlier in the context of this particular inspection job as derived by the task analysis. A major prerequisite was that it be a progressive part training scheme which enabled the inspectors to build their repertoire of knowledge and skills in an orderly manner. A typical training session proceeds as follows:

1. Initial Overview: Initially the subjects use the introduction module and are introduced to basic lens terminology and familiarized with the computer program. Following familiarization training, subjects are quizzed on their knowledge of the operation of the computer program and correct answers are supplied for incorrect responses.
2. Standards Training: Since a progressive parts training approach is used, the subjects are initially trained on only two types of defects. Subjects are shown different instances of each defect with their names and probable locations (cueing).
3. Defect Naming: Lenses with a single defect are displayed on the screen and trainees classify the defects by defect name (active response). Trainees are provided with immediate feedback after each response.
4. Search Training: Trainees are shown lens images with and without defects. The inspectors search for the defect and respond by clicking on the defect. Subjects are provided immediate and end-of-session feedback on search performance.
5. Decision Training: Initially, training is provided on rules which are used to classify the lenses as conforming and non-conforming. Trainees are shown lens images with single defects marked. Trainees classify the defects and, based on the defect type, severity and location classify the lens. Trainees are provided immediate feedback on decision performance.

   Thus, the trainees are trained on the search and decision aspects separately. Later, defects are combined progressively and steps 2 through 5 are repeated. Then subjects are trained on the search and decision aspects for different combinations of defects. At each step, immediate feedback is provided on search and decision making performance.

6. Training on the Whole Task: All defects are considered in developing representative batch files of conforming and nonconforming lenses. The percentage nonconforming in each batch file is the same as that which would exist in the actual production environment. In this type of training, the trainees have to first visually search for all the defects in a single lens image and name the defects. On location of defects, the subjects classify the lens as conforming or non-conforming based on the defect severity, number of defects and the location. Trainees are provided with both immediate performance feedback after inspecting each lens image and end of session feedback. The feedback is reduced as the desired proficiency level is reached.

CONCLUSIONS

The high degree of control that ASSIST affords will create the opportunity to systematize the training. In addition, there are several other inherent advantages that will serve to the alleviate the problems characteristic of OJT:

Completeness. Inspectors can be exposed to a wide variety of defects, with varying degrees of severity, at different locations, through the use of a library of defect images. Inspectors can also be trained on less frequently occurring critical defects.

Adaptability. ASSIST can be modified to meet the needs of individual inspectors. Batch files of images can be created to train inspectors on particular aspects of the inspection task with which they have the greatest difficulty. Thus, the program can be tailored to accommodate individual differences in inspection abilities.

Efficiency. Since the training will be more intensive, the trainees will be able to become more skilled within a shorter period of time.

Integration. The training system will integrate different training methods (e.g., feedback training, feed-forward training, and active training) into a single comprehensive training program.

Certification. ASSIST can be used as part of the certification process. Since the record keeping process can be automated, instructors can more easily monitor and track an individual's performance, initially for training and later for retraining.

Instruction. ASSIST could be used by instructors in FAA certified A&P school for training. In this manner, for example, aircraft maintenance technicians could gain exposure to defects on wide-bodied aircraft that they might not have otherwise.

The paper has described research in the area of aviation maintenance and inspection currently underway at Clemson University. Through the development and systematic application of human factors techniques, the research aims at improving the effectiveness and efficiency of aircraft visual inspection. The results of the research effort have been made available to the aviation maintenance community as deliverable products in the form of usable CD-ROMs. It is anticipated that the use of these products would lead to improved airworthiness of the U. S. domestic aircraft fleet. Subsequent phases of this research will evaluate the utility of ASSIST in an operational setting. Finally, this research has future implications as well. Human performance models could potentially be used in conjunction with ASSIST for a wide range of controlled studies to both 1) evaluate the effect of various task and subject factors on aircraft inspection performance, and 2) identify specific interventions to enhance performance.

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